SOURCES AND CONCENTRATIONS OF ORGANIC COMPOUNDS IN INDOOR ENVIRONMENTS*

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All occupied buildings have various sources of indoor air pollution. Humans (and their household pets) generate carbon dioxide, moisture, odors, and microbes simply through normal living processes. Other more important sources of indoor air pollution are combustion appliances (gas stoves, unvented space heaters), materials used in construction, furnishings, and insulation, and the soil under and around houses. These sources release carbon monoxide, nitrogen dioxide, formaldehyde and other organic compounds, particulates, and radon. Table I summarizes the sources and types of air pollutants commonly found indoors.

This paper will discuss the sources and concentrations of organic compounds in indoor environments. Formaldehyde, as an indoor pollutant, has been extensively investigated; however, recent work at Lawrence Berkeley Laboratory and elsewhere is now focussed on a broad range of organic compounds, in addition to formaldehyde.

Formaldehyde is an inexpensive chemical used in large volumes throughout the world in a variety of products, mainly in the urea, phenolic, melamine, and acetal resins present in insulation materials, particleboard, plywood, textiles, adhesives, etc. used in large quantities by the building trades. Although particleboard and urea-formaldehyde foam insulation have received most attention, some of the combustion processes mentioned above also release formaldehyde. The pungent and

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TABLE I

SUMMARY OF SOURCES AND TYPES OF INDOOR AIR POLLUTANTS

Sources	*Pollutant types*
Outdoor	
Stationary sources	SO_2, CO, NO, NO_2, O_3, hydrocarbons, particulates
Motor vehicles	CO, NO, NO_2, lead, particulates
Soil	Radon
Indoor	
Building construction materials	
Concrete, stone	Radon and other radioactive elements
Particleboard	Formaldehyde
Insulation	Formaldehyde, fiberglass
Fire retardant	Asbestos
Adhesives	Organics
Paint	Organics, lead, mercury
Building contents	
Heating and cooking combustion appliances	CO, NO, NO_2, formaldehyde, particulates
Copy machines	Organics
Water service; natural gas	Radon
Human occupants	
Metabolic activity	H_2O, CO_2, NH_3, organics, odors
Biological activity	Microorganisms
Human activities	
Tobacco smoke	CO, NO_2, HCN, organics, odors, particulates
Aerosol spray devices	Fluorocarbons, vinyl chloride, CO_2, odors
Cleaning and cooking products	Organics, odors
Hobbies and crafts	Organics, odors

characteristic odor of formaldehyde can be detected by most people at levels below 100 μg./m.[3] Several studies indicate that concentrations in the range of 100 to 200 μg./m.[3] may be sufficient to cause swelling of the mucous membranes, depending on individual sensitivity and environmental conditions (temperature, humidity, etc.). Burning of the eyes, weeping, and irritation of upper respiratory passages can also result from exposure to relatively low concentrations. High concentrations ($\sim$ 1,000 μg./m.^{3}) may produce coughing, constriction in the chest, and a sense of pressure in the head. There is concern that formaldehyde may have serious long-term health effects. Several foreign countries and various states in the United States are moving rapidly to establish standards for

TABLE II

SUMMARY OF FORMALDEHYDE MEASUREMENTS IN VARIOUS INDOOR ENVIRONMENTS

Sampling site	*Concentration* (ppm.)†* Range	Mean
Two mobile homes in Pittsburgh, Pa.	0.1-0.8‡	0.36
Mobile homes registering complaints in state of Washington	0-1.77	0.1-0.44
Mobile homes registering complaints in Minnesota	0-3.0	0.4
Mobile homes registering complaints in Wisconsin	0.023-4.2	0.88
Public buildings and energy-efficient homes, occupied and unoccupied	0-0.021 [0-0.23]‡	— —

* Formaldehyde, unless otherwise indicated.
† 1 ppm. = 1,200 μg./m^3.
‡ Total aliphatic aldehydes
Source: National Research Council, National Academy of Sciences[1]

formaldehyde concentrations in indoor air. The range of these proposed standards is 120 to 600 μg./m.^{3} A summary of formaldehyde measurements in various indoor environments is given in Table II.[1]

Formaldehyde and total aliphatic aldehydes (formaldehyde plus other aliphatic aldehydes) have been measured at several energy-efficient houses at various geographic locations in the United States. Figure 1 shows a histogram of frequency of occurrence of concentrations of formaldehyde and total aliphatic aldehydes measured at an energy-efficient house with an air exchange rate of 0.2 ach. Data taken at an energy-efficient house in Mission Viejo, Calif., are shown in Table III. As shown, when the house did not contain furniture, formaldehyde levels were below 120 μg./m.^{3}; when furniture was added, formaldehyde levels rose to almost twice the 120 μg./m.^{3} level. A further increase was noted when the house was occupied, very likely because of such activities as cooking with gas. When occupants opened windows to increase ventilation, formaldehyde levels dropped substantially.

In the past few years office workers throughout the country have registered numerous complaints of "bad air." These complaints come most frequently from workers occupying new office buildings with hermetical-

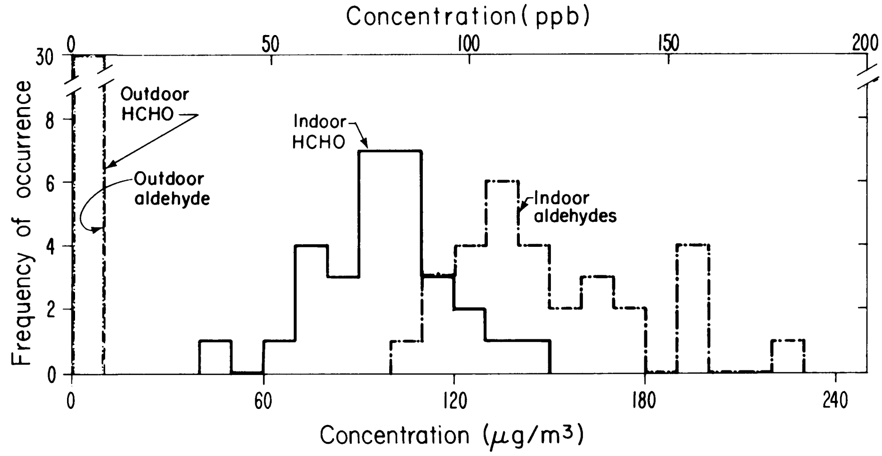

Fig. 1. Histogram of indoor and outdoor formaldehyde concentrations at an energy-efficient house

ly sealed windows. Although various government agencies have investigated these problems, the etiological agents have frequently remained unidentified.

One primary contributor to poor indoor air quality in office buildings may be organic contaminants, which have numerous indoor sources: building materials, cleaning products, tobacco smoking, furnishings, common consumer products, and the building occupants themselves. To date, however, there has been relatively little research on this topic. In 1980 our laboratory began a comprehensive program in collaboration with the Center for Disease Control and the National Institute of Occupational Safety and Health to characterize indoor air pollution in "complaint" office buildings.

The results of work in one of the office buildings[2] are summarized in Table IV. Only total hydrocarbons exceeded air quality standards; no other indoor pollutants, including formaldehyde, exceeded air quality standards. The average total hydrocarbon concentration was 1,627 $\pm$ 26 μg./m.^{3} (2.5 ppm. expressed as methane). The average indoor concentration can be compared to the average outdoor concentration of 210 $\pm$ 60 μg./m.^{3} (0.32 ppm.). These hydrocarbon concentrations, especially the indoor values, are well in excess of the National Ambient Air Quality Standard of 160 μg./m.^{3} (0.24 ppm.). It must be emphasized, however, that this standard was established on the basis of hydrocarbons acting as

TABLE III

INDOOR FORMALDEHYDE CONCENTRATIONS IN A NEW RESIDENTIAL BUILDING

Condition	*Formaldyhyde* (*μg./m.*^{3})
Unoccupied, without furniture*	80 ± 9%
Unoccupied, with furniture*	223 ± 7%
Occupied, day*	261 ± 10%
Occupied, night†	140 ± 31%
Outdoor air	<20

* Air exchange rate ≃ 0.4
† Windows open part of time; air exchange rate significantly greater than 0.4 and variable.

precursors for photochemical smog, and does not necessarily imply that hydrocarbons themselves are harmful.

The observation of high total hydrocarbon concentrations led us to investigate in some depth the organic compounds in several office buildings. Figure 2 shows typical comparative gas chromatograms of equal volumes of air taken simultaneously inside and outside an office building where complaints had been registered.[3] Organic contaminants are greater in number and concentration indoors than outdoors, as indicated by the sizes and number of peaks. For a few samples, comparison of peak areas with those of external standards indicated that the largest peaks corresponded to air concentrations of a few parts per billion.

Samples were analyzed by gas chromatography-mass spectrometry to establish identities. Generally, the largest peaks fell into one of three classes of compounds, the largest being aliphatic hydrocarbons including straight-chain and derivatives of cyclohexane. These hydrocarbons are derived from petroleum distillate-type solvents. The second largest class was alkylated aromatic hydrocarbons, predominantly toluene but including xylenes, trimethyl-and other substituted benzenes, and even methyl and dimethylnapthalenes. These compounds are either solvents themselves or constituents of naphenic-type petroleum solvent mixtures. The third class observed was chlorinated hydrocarbons, predominantly tetrachloroethylene, 1,1,1,-trichloroethane, and tri-chloroethylene. Miscellaneous other compounds included ketones, aldehydes, and benzene. Table V lists those organic compounds found to be at least five times as

TABLE IV

SUMMARY OF AVERAGE INDOOR AIR QUALITY MEASUREMENTS IN AN OFFICE BUILDING AND AIR QUALITY STANDARDS

	Office building air quality		*Air quality standards*	
Contaminant	*Concentration*	*Averaging time*	*Concentration*	*Averaging time*
Carbon monoxide	4.6 mg./m.^{3} (4 ppm.)	1 hr.	40 mg./m.^{3} (35 ppm.)*	1 hr.
Carbon dioxide	1,800 mg./m.^{3} (1,000 ppm.)	8-10 hrs.	9,000 mg./m.^{3}† (5,000)	8 hrs.
Nitrogen dioxide	60 μg./m.^{3} (30 ppb.)	1 week	100 μg./m.^{3}(50 ppb.)*	1 yr.
Hydrocarbons (nonmethane)	1,627 μg./m.^{3} (2.5 ppm.)	30 minutes	160 μg./m.^{3}* (0.24 ppm.)	3 hours (6-9 am.)
Formaldehyde	49 μg./m.^{3} (41 ppb.)	6 hours	120-840 μg./m.^{3}‡ (100-700 ppb.)	maximum
Aliphatic aldehydes	108 μg./m.^{3} (90 ppb.)	6 hours	No standard	
Particulates	31 μg./m.^{3}	12 hours	75 μg./m.^{3}*	1 yr.
			260 μg./m.^{3}*	24 hours
Lead	0.2 μg./m.^{3}	12 hours	1.5 μg./m.^{3}§	3 months
Sulfur (as SO_4)	2.5 μg./m.^{3}	12 hours	25 μg./m.^{3}§	24 hours
Airborne microbes	179 CFP./m.^{3}	20 minutes	No standard	

* U.S. EPA Ambient Air Quality Standard for outdoor air
† State of California Air Quality Standard
‡ Range of recommended standards
§ U.S. Occupational Safety and Health Administration

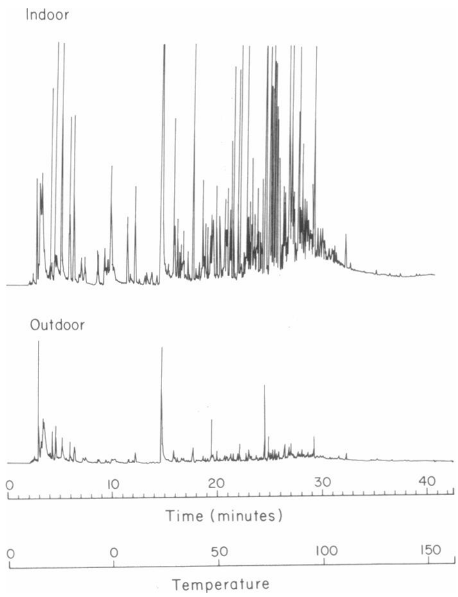

Fig. 2. Comparative gas chromatograms of indoor and outdoor air at an office site

great inside offices as outdoors, and notes, where applicable, the standards of exposure promulgated by the Occupational Safety and Health Administration for workplace environments. In research now in progress, we are quantitatively determining the concentrations of these organic compounds by current state-of-the-art analytic procedures, which, although they provide only rough estimates, are indicating concentrations ranging from 1 to 100 ppb. These levels are well below existing limits established for occupational exposure but may be excessive for the general public for whom limits are typically 10 times lower.

While no single compound was present in high enough concentration to be singled out as a health hazard by existing Occupational Health and Safety Administration criteria, the potential health hazard from the combined effects of the organic compounds found in these samples cannot be assessed at this time. The existing health criteria may be inadequate given that: additive or synergistic effects are not adequately addressed; criteria are generally based on acute exposure studies whereas this exposure is chronic; the population at risk is more diverse including women and elderly workers; and annoyance from odorant effects is not considered.

TABLE V

ORGANIC COMPOUNDS DETECTED IN OFFICE BUILDINGS

Organic compound	*OSHA permissible exposure limit (ppm.)*
Hydrocarbons	
n-hexane	500
n-heptane	500
n-octane	500
n-nonane	
n-undecane	
2-methylpentane	500
3-methylpentane	
2,5-dimethylpentane	
methylcyclopentane	
ethylcyclohexane	
methylcyclochexane	500
pentamethylheptane	
Aromatics	
benzene	1
xylenes	100
toluene	200
Halogenated Hydrocarbons	
tricloroethane	350
tricloroethylene	100
tetrachloroethylene	100
Miscellaneous	
hexanal	
methylethylketone	200

A summary of organic compounds identified in indoor environments is given in Table VI. Several sources of organic contaminants in closed office spaces can be categorized as: new building materials, aged building materials, wet-process photocopiers, tobacco smoke, and building maintenance products. Table VII summarizes the source characteristics and generation pattern for organic contaminants in a typical office space.[4] New building materials are a source of organic contaminants because they contain residual solvents and other compounds remaining after the process of manufacture. Qualitative analysis of the headspace vapor standing over a variety of new building materials has revealed a great number of compounds—predominantly toluene and aliphatic hydrocarbons. Ketonic solvents were observed as well as such specialty compounds as butylated hydroxytoluene.

TABLE VI

ORGANIC COMPOUNDS IN INDOOR ENVIRONMENTS

Compounds	*Health effects*	*Sources and/or uses*
Formaldehyde and other aldehydes	Eye and respiratory irritation; may have more serious long-term health effects	Out-gassing from buildings materials—particle board, plywood, and ureaformaldehyde insulation foam; also generated by cooking and smoking
C_n Alkanes N = 5~16	Narcotic at high concentrations; moderately irritating	Gasoline, mineral spirits, solvents, etc.
C_n Alkenes N = 5~16	Similar to that of alkanes	Similar to that of alkanes
Benzene	Respiratory irritation; recognized carcinogen	Plastic and rubber solvents; from cigarette smoking; used in paints and varnishes, including putty, filler, stains, and finishes
Xylene	Narcotic; irritating; high concentrations may cause injury to heart, liver, kidney, and nervous system	Used as solvent for resins, enamels, etc.; also used in nonlead automobile fuels and in manufacture of pesticides, dyes, pharmaceuticals
Toluene	Narcotic; may cause anemia	Solvents; by-product of organic compounds used in several household products
Styrene	Narcotic; can cause headache, fatigue, stupor, depression, incoordination, and possible eye injury	Widely used in manufacture of plastics, synthetic rubber and resins
1,1,1-Trichloroethane	Subject of OSHA carcinogenesis inquiry	Aerosol propellant, pesticide, cleaning solvents
Trichloroethylene	Animal carcinogen; subject of OSHA carcinogenesis inquiry	Oil and wax solvents, cleaning compounds, vapour degreasing products, dry cleaning operations; also used as an anaesthetic
Ethyl Benzene	Highly irritating to eyes, etc.	Solvents; used in Styrene related products
Chloro Benzenes	Strong narcotic; possible lung, liver, and kidney damage	Used in production of paint, varnish, pesticides, and various organic solvents
Polychlorinated biphenyls (PCB's)	Suspected carcinogens	Used in various electrical components; may appear in waste oil supplies and in plastic and paper products in which PCB's are used as plasticizers
Pesticides	Suspected carcinogens	Used for insect control

TABLE VII

CHARACTERISTICS OF SOURCES OF ORGANIC CONTAMINANTS IN A TYPICAL OFFICE SPACE*

	Nominal emission rate (gm./hr.-office)	*Generation pattern*	*Nominal 8 hr. TWA exposure at 1.0 acph (mg. – hr./m.^{3})*	*Major known types of organic contaminants emitted*
New building materials	10**	Continuous	29	Aliphatic hydrocarbons
				Aromatic hydrocarbons
				Ketones
				Esters
				Formaldehyde
				Miscellaneous organics
Aged building materials	Low	Continuous	Low	Formaldehyde
Wet-process photocopiers	25†	Workday	67	Aliphatic hydrocarbons
Smokers	0.35†	Workday	0.9	Formaldehyde
	0.15‡		0.4	Acrolein
	0.25‡	0.7		Nicotine
	(4)‡			Total particulates
			10	Miscellaneous organics
Building maintenance products	100	Epidodic	36§	Aliphatic hydrocarbons
				Aromatic hydrocarbons
				Formaldehyde
				Amines
				Chlorinated hydrocarbons
				Miscellaneous organics

* The typical office being considered has dimensions of 100 x 100 x 10 ft.^{3} with an occupancy of 40 workers.
** Emission rate calculated assuming 1.0 mg./ft.^{2} for wall-to-wall carpeting after several months.
† Emission rate calculated assuming one wet-process photocopier using 1,000 gm. of fluid per week.
‡ Calculated from data in Weber, A., Jermini, z., and Grandijian, E.: Irritating effects on man of air pollution due to cigarette smoke. *Am. J. Public Health 66*'672-76, 1976.
§ Emission rate calculated assuming 100 gm. of product (floor detergent or dusting fluid) applied in one hour.

Implementation of control strategies for organic contaminants in indoor environments must consider the nature and generation pattern of each source. For new building materials, further research may define an acceptable waiting period prior to occupancy or a period of high ventilation rates while they "dry out". Workday pollution from photocopiers and tobacco smoke may be reduced by increased ventilation, but not as efficiently as source removal itself. Episodic contaminant generation from building maintenance products can be reduced by increased ventilation, but a better strategy may be to offset product use from the workday period.

Questions and Answers

MISS BARBARA EISLER (American Lung Association of New Jersey): Have you come across or devised any remedial measures to reduce any indoor air pollutants?

DR. HOLLOWELL: In residential buildings we have done a considerable amount of work in evaluating heat exchangers. These devices allow one to ventilate an energy-efficient structure by exhausting the warm indoor polluted air past a membrane, recovering the heat, and providing ventilation at a high air-exchange rate in an energy-efficient manner. We are also looking at other devices. A number of other institutions are looking at radon control, as was mentioned yesterday by Dr. Harley.

MISS EISLER: Is there a method that people not going to invest in a heat exchanger can utilize to get some balance between "buttoning up" and properly ventilating their homes to maintain healthy air?

DR. HOLLOWELL: Well, I think the heat exchanger is currently the best method for a residential building.

MISS EISLER: And the most expensive.

DR. EISENBUD: There is an implication in your question, and that is the concentration of volatile organic compounds at which control is indicated or required. This is something that I would hope could be discussed.

MISS EISLER: In the work that I have been looking into, I have come up with enough indications that there are problems. We get calls from people who want to know what to do and we are saying, "We don't know." Yes, it is a good idea to ventilate a house, but how much? What do people do while this is under study?

DR. HOLLOWELL: The proper level of ventilation is still a large topic of debate. ASHRAE has spent considerable time looking at this issue, and they recommend ventilation rates for all types of building spaces.

MR. ALAN STERN (New York City Department of Health): Have you attempted to separate out the organics, the volatile organics or organics in general resulting from tobacco smoke or the organics you see in your gas chromatographs? What percent of the organics might result from tobacco smoke?

DR. HOLLOWELL: I do not know. Both office buildings in one study, the control building and the complaint building, had about 35 to 40% smokers. Based on the carbon monoxide and the particulate levels observed, I do not think that smoking contributed heavily to the hydrocarbon or organic levels observed in those buildings.

DR. PRESTON MCNALL (Bureau of Standards): You seemed to indicate that the numbers that you were measuring were quite low but that people complained. Do you have any explanation for the fact that they were perceiving something that they should not be able to perceive?

DR. HOLLOWELL: The only conclusion that we might offer is that the composite effect of all these organic compounds is something that needs to be investigated. The total hydrocarbon concentration in office buildings is on the order of several ppm., 10 to 50 ppm., and these levels may give rise to health effects.

DR. MCNALL: You spoke about the General Services Administration building. Was that a Social Security payment center?

DR. HOLLOWELL: Yes.

DR. MCNALL: Those buildings have some other problems with which I happen to be familiar. One of them is temperature. Is there any information on complaints of stuffiness because an area was too hot?

DR. HOLLOWELL: We measured temperature and humidity, and no problems were associated with these parameters.

MR. HARVEY SACHS (Princeton University): Your mobile lab and GEOMET lab have enormous experience now with formaldehyde. In what fraction of energy-conserving, tight houses have you had the sense that there is a problem?

DR. HOLLOWELL: We have checked, at most, a dozen houses with our mobile laboratory, and Demetrios Moschandreas can talk about the houses he has studied. We have not found excessive levels of formaldehyde in these houses. Two hundred to 300 parts per billion has been the highest that we have observed; however, Demetrios may have found higher levels. We have not looked at mobile homes, and those seem to be environments where the formaldehyde levels are high: several hundred ppb. and low ppm. ranges have been observed in mobile homes.

DR. DEMETRIOS MOSCHANDREAS (GEOMET Technologies, Inc.): I have looked in mobile homes, and we have indeed found levels as high as about 700 ppb. or 0.7 ppm. I just finished a study for the Environmental Protection Agency where we investigated formaldehyde levels from wood-burning houses. I recall that we did not measure concentrations higher than 0.2 ppm., a value suggested as an indoor formaldehyde standard. These values appear to reflect the indoor formaldehyde concentrations in conventional residences. What do we do about elevated indoor pollutant concentrations? I suggest that you open the windows in your building. Control of indoor air pollution is a very complex issue because it depends on the indoor source and cost-effectiveness factors. If an occupant smells formaldehyde, opening the window will reduce the indoor levels.

DR. EISENBUD: I think this raises an interesting point. There has not yet been any discussion about organic products that come from a cookstove. We ought to bear in mind that we have been talking about the elite among the housing structures, the new, modern ones. A week ago today, I was in a rather poor farmhouse in Brazil. They were cooking on an open stove and had butchered veal hanging overhead to be smoked. In other words, their practice was to smoke the veal from whatever was coming through the smoke of the cookstove. This brings to mind all of the data that I have seen about emissions in relatively primitive dwellings. There is research on carbon monoxide and particulates, but I have not seen anything on organics. Do you want to comment on that?

DR. HOLLOWELL: We have done a little work measuring formaldehyde emissions from gas stoves. If one cooks certain foods such as spinach or cabbage, one could elevate aldehyde levels considerably, so when one starts looking at the foods used in building spaces a new research study may result.

MR. SACHS: Would you review the area of heat exchangers? Some people think this is a terribly intimidating thing. It is really a very small item to include in an air-handling system, particularly at the residential level.

DR. HOLLOWELL: A heat exchanger has a core which is either made of aluminum or plastic—one type is constructed with treated paper. A heat exchanger recovers the heat from the exhaust air stream and transfers it to the cold "fresh air" outdoor air stream entering the house. A simple heat exchanger unit mounts into a window opening and costs about $200. It is sufficient to ventilate one or two small rooms. Other units can be integrated with the central air-distribution system associated with the furnace. In Europe, Sweden in particular, heat exchangers are being installed in many new houses. It is quite expensive when it is a central system. Europeans are even willing to pay to retrofit an existing house, including installation of the duct work, because Europeans typically do not have central forced air systems in their houses. Europeans are even willing to pay $3,000 to $4,000 to install these systems.

We have estimated that to reduce the air exchange rate in a house from 0.75 air changes per hour, a typical rate for most houses in the United States, to 0.5 or 0.4 air changes per hour and to install a heat exchanger so that the ventilation rate for the house is about one air change per hour would cost something on the order of $1,000, including the weatherization component and the heat exchanger. Whether people are willing to pay for this or not is certainly an open question for the United States.

DR. MCNALL: The idea of spending that $1,000 that you mentioned for that purpose is fine if you know you have a problem. What I submit is that we do not know where the problems are out there, and if you take the 80 million existing homes and talk about $1,000 each, that is $80 billion which you would spend to retrofit all those houses. It is really a very serious economic problem.

DR. HOLLOWELL: That is right. The problem of identifying houses for radon or formaldehyde problems is not trivial. Through the development of passive monitors one may be able to identify certain high radon areas in the United States or certain indoor air pollution problem houses. One may then recommend retrofitting these problem houses with heat exchangers. Some people are clearly willing to pay for heat exchangers on their own merits because they perceive a health problem; this is certainly the case in Europe. People are very aware of indoor air pollution problems in Sweden and Denmark and are willing to pay whatever it takes to maintain a healthy indoor environment.

DR. EISENBUD: But we have not established that this indoor environment is unhealthy; it is merely unpleasant.

DR. HOLLOWELL: Yes, that is right.

DR. EISENBUD: We ought to remember that housing represents an enormous environmental problem in this country. Go a few blocks north of here and see the way people live. Imagine their aspirations to get into a new house without rats and vermin, even if it means breathing a little formaldehyde. So I think these things have to be traded off, and probably one of the largest capital investments that this country is going to have to make some day is to take care of substandard housing. I would think that in the environmental priorities we would have to be very careful that we do not divert some of that money into areas where it has not been established that problems exist.

MR. HOPKINS (New York City Health Department): How old are the buildings that your company tested?

DR. HOLLOWELL: They are typically a few months to five years old.

MR. HOPKINS: And how long were they standing prior to occupancy? By that I mean a building is constructed and then it is furnished, and soon after that the people move in. I was wondering whether or not there may have been adequate ventilation to remove these odors.

DR. HOLLOWELL: Well, that is a good questions because at our laboratory we looked at buildings where occupants moved in immediately upon completion of the building. One control scenario, if these compounds are coming off with a relatively short half-life, may be to ventilate the building at a high rate initially and then to reduce the ventilation rate with time. In the large office buildings we looked at buildings occupied for at least two years after they had built up a history of complaints.

MR. HOPKINS: Has it been determined how long it takes for these vapors or odors to dissipate once the building is up?

DR. HOLLOWELL: No, it has not been determined.

DR. MERRIL EISENBUD (New York University): Is there somebody who can tell us about what is released when food is cooked? Certainly the most pervasive smell in most residential environments is the smell of food that is being cooked. Frequently, a haze is visable also.

DR. JAMES REPACE (U.S. Environmental Protection Agency): I cannot attest to what organics might be coming off when food is cooked. I have made measurements in my kitchen between cooking times. There is a typical respirable particle level of 20 micrograms per cubic meter, whereas levels as high as 900 micrograms per cubic meter have been measured during broiling. These levels have caused respiratory distress among atopic members of the family. What those respirable particles are, I have no idea, but certainly levels that high are potentially harmful.

DR. LAWRENCE HINKLE (New York Hospital-Cornell Medical Center): A very important point has been raised here. As I pointed out yesterday, one characteristic of indoor space is density of people and another characteristic is the human activity that goes on in it. We presented a good deal of data yesterday to show that many potentially lethal and illness-causing substances in indoor air originate from people, from people's activities, and from things that people carry indoors and use.

I am much impressed with the sophistication with which odor, particles, and gases are being measured in new buildings. However, I do think that the authors need to be cautious and to use sophistication in evaluating whether or not and in what way the substances that they are measuring have health effects. We cannot simply assume that a complaint is a health effect. The magnitude and the nature of health effects must be weighed, and the cost of protecting people from these health effects, which is sometimes great, must be weighed also.

DR. HOLLOWELL: Your point is well taken. From a historic point of view, I should comment on how we got involved in looking at organics. In these buildings, other groups had done measurements for formaldehyde using Draegar tubes or the chromotropic acid method. They had come up with formaldehyde levels that were several hundred ppb. Our work developed an improved formaldehyde measurement method which showed that the formaldehyde levels were not excessive; this then led us to look at other organic compounds.

Your point is well taken; these complaints may be comfort complaints and not really health-related problems. I think a lot of caution needs to be taken in looking into these complaint cases. The Center for Disease Control is building up a large file. We do not know if these are health effects; it is still an open issue.

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